

*What is claimed is:*

CLAIMS

1. A battery cell electrolyte, comprising:
  - 5 a) a main solvent of an electrolyte solvent mixture, having the chemical formula  $R_1(CH_2CH_2O)_nR_2$ , where n ranges between 1 and 10,  $R_1$  and  $R_2$  are different or identical groups selected from the group consisting of alkyl, alkoxy, substituted alkyl, and substituted alkoxy groups; and
  - 10 b) an oxidizing agent additive comprising no more than about 49% by weight of the electrolyte solvent mixture.
2. The electrolyte of claim 1, wherein the oxidizing agent additive is at least one of sulfur dioxide, nitrous oxide, carbon dioxide, a halogen, an interhalogen, an oxychloride, a sulfur monochloride, a vinyl carbonate, and halogenated carbonates.
- 15 3. The electrolyte of claim 2, wherein the halogen is selected from the group consisting of  $Cl_2$ ,  $Br_2$  and  $I_2$ .
4. The electrolyte of claim 2, wherein the oxychloride is selected from the group consisting of  $SO_2Cl_2$  and  $SOCl_2$ .
5. The electrolyte of claim 2, wherein the interhalogen is selected from the group consisting of iodine monochloride ( $ICl$ ), iodine trichloride ( $ICl_3$ ) and iodine monobromide  $I_2Br_2$ .

6. The electrolyte of claim 1, wherein the oxidizing agent additive has a stronger oxidizing ability than elemental S.

7. The electrolyte of claim 1, further comprising a dioxolane as a co-solvent.

5 8. The electrolyte of claim 7, wherein the dioxolane co-solvent comprises less than about 20% by weight of the electrolyte solvent mixture.

9. The electrolyte of claim 1, wherein said main solvent is a linear polyether.

10. The electrolyte of claim 1, wherein said main solvent is chosen from 10 the glyme family [  $\text{CH}_3\text{O}(\text{CH}_2\text{CH}_2\text{O})_n\text{CH}_3$  ] including monoglyme, diglyme, triglyme, and tetraglyme.

11. The electrolyte of claim 1, wherein said main solvent is dimethoxyethane.

12. The electrolyte of claim 1, further comprising a second co-solvent 15 having a donor number of at least about 13.

13. The electrolyte of claim 12, wherein said second co-solvent is at least one of hexamethylphosphoramide, pyridine, N,N-diethylacetamide, N,N-diethylformamide, dimethylsulfoxide, tetramethylurea, N,N-dimethylacetamide, N,N-dimethylformamide, tributylphosphate, trimethylphosphate N,N,N',N'- 20 tetraethylsulfamide, tetramethylenediamine, tetramethylpropylenediamine, and pentamethyldiethylenetriamine.

14. The electrolyte of claim 1, further comprising an electrolyte salt.

15. The electrolyte of claim 14, wherein said electrolyte salt is at least one of LiN(C<sub>2</sub>F<sub>5</sub>SO<sub>2</sub>)<sub>2</sub>, LiN(CF<sub>3</sub>SO<sub>2</sub>)<sub>2</sub>, LiCF<sub>3</sub>SO<sub>3</sub>, LiClO<sub>4</sub>, LiPF<sub>6</sub>, LiBF<sub>4</sub>, LiAsF<sub>6</sub>.
16. The electrolyte of claim 1, wherein said electrolyte is in a liquid state.
17. The electrolyte of claim 1, wherein said electrolyte is in a gel state.
- 5 18. The electrolyte of claim 1, wherein said electrolyte is in a solid state.
19. A negative electrode, comprising:
- a) a lithium material; and
- b) a film coating said lithium material, said film formed by treating said lithium material with an oxidizing agent prior to incorporation of said electrode into a battery cell.
- 10 20. The negative electrode of claim 19, wherein the oxidizing agent is at least one of sulfur dioxide, nitrous oxide, carbon dioxide, a halogen, an interhalogen, an oxychloride, a sulfur monochloride, a vinyl carbonate and halogenated carbonates.
21. The negative electrode of claim 20, wherein the halogen is selected from the group consisting of Cl<sub>2</sub>, Br<sub>2</sub> and I<sub>2</sub>.
- 15 22. The negative electrode of claim 20, wherein the oxychloride is selected from the group consisting of SO<sub>2</sub>Cl<sub>2</sub> and SOCl<sub>2</sub>.
23. The negative electrode of claim 20, wherein the interhalogen is selected from the group consisting of iodine monochloride (ICl), iodine trichloride (ICl<sub>3</sub>) and iodine monobromide I<sub>2</sub>Br<sub>2</sub>.

24. The electrode of claim 19, wherein said lithium material is comprised of at least one of lithium metal, a lithium alloy, and a lithium insertion compound.

25. A battery cell comprising:

- a) a negative lithium electrode;
- 5 b) a positive electrode comprising an electrochemically active material;
- c) an electrolyte including a
  - i) a main solvent of an electrolyte solvent mixture, having the chemical formula  $R_1(CH_2CH_2O)_nR_2$ , where n ranges between 1 and 10,  $R_1$  and  $R_2$  are different or identical groups selected from the group consisting of alkyl, alkoxy, substituted alkyl, and substituted alkoxy groups; and
  - 10 ii) an oxidizing agent additive

26. The battery cell of claim 25, wherein the oxidizing agent additive is at least one of sulfur dioxide, nitrous oxide, carbon dioxide, a halogen, an interhalogen, 15 an oxychloride, a sulfur monochloride, a vinyl carbonate, and halogenated carbonates.

27. The battery cell of claim 25, wherein said electrochemically active material comprises sulfur in the form of at least one of elemental sulfur, a metal sulfide, a metal polysulfide, an organosulfur material, and combinations thereof, 20 wherein said metal is selected from the group consisting of alkali metals, alkaline earth metals, and mixtures of alkali and alkaline earth metals.

28. The battery cell of claim 25, wherein said electrochemically active material comprises Li<sub>2</sub>S<sub>8</sub>.

29. The battery cell of claim 25, further comprising a first dioxolane co-solvent, comprising no more than 20% by weight of the electrolyte solvent mixture.

5 30. The battery cell of claim 25, further comprising a second co-solvent having a donor number of at least about 13.

31. The battery cell of claim 30, wherein said second co-solvent is at least one of hexamethylphosphoramide, pyridine, N,N-diethylacetamide, N,N-diethylformamide, dimethylsulfoxide, tetramethylurea, N,N-dimethylacetamide, N,N-dimethylformamide, tributylphosphate, trimethylphosphate N,N,N',N'-tetraethylsulfamide, tetramethylenediamine, tetramethylpropylenediamine, and pentamethyldiethylenetriamine.

32. The battery cell of claim 25, further comprising an electrolyte salt.

33. The battery cell of claim 32, wherein said electrolyte salt is at least one of LiN(C<sub>2</sub>F<sub>5</sub>SO<sub>2</sub>)<sub>2</sub>, LiN(CF<sub>3</sub>S0<sub>2</sub>)<sub>2</sub>, LiCF<sub>3</sub>S0<sub>3</sub>, LiClO<sub>4</sub>, LiPF<sub>6</sub>, LiBF<sub>4</sub>, LiAsF<sub>6</sub>.

34. The battery cell of claim 25, wherein said electrolyte is in a liquid state.

35. The battery cell of claim 25, wherein said electrolyte is in a gel state.

36. The battery cell of claim 25, wherein said electrolyte is in a solid state.

37. The battery cell of claim 25, wherein said electrolyte is a catholyte comprising a dissolved lithium polysulfide.

38. A method of making a protected lithium electrode battery cell, comprising:

- a) treating a lithium material with an oxidizing agent to form a negative electrode having a protective film;
- 5 b) forming a positive electrode comprising an electrochemically active material; and
- c) combining said negative and positive electrodes with an electrolyte following the treating of said lithium material.

39. The method of claim 38, wherein said positive electrode comprises  
10 sulfur in the form of at least one of elemental sulfur, a metal sulfide, a metal polysulfide, an organosulfur material, and combinations thereof, wherein said metal is selected from the group consisting of alkali metals, alkaline earth metals, and mixtures of alkali and alkaline earth metals.

40. The method of claim 38, wherein said electrochemically active  
15 material comprises  $\text{Li}_2\text{S}_8$ .

41. The method of claim 38, further comprising interposing an electrolyte separator between said positive and negative electrodes.

42. The method of claim 38, wherein the oxidizing agent is at least one of  
sulfur dioxide, nitrous oxide, carbon dioxide, a halogen, an interhalogen, an  
20 oxychloride, a sulfur monochloride, a vinyl carbonate, and halogenated carbonates.

43. A method of making a protected lithium electrode battery cell, comprising:

- a) forming a negative electrode comprising a lithium material;
- b) forming a positive electrode comprising an electrochemically active material; and
- c) combining said negative and positive electrodes with an electrolyte containing an oxidizing agent additive wherein the oxidizing agent additive reacts with the lithium material of the negative electrode to form a protective film on the negative electrode.

5           44. The method of claim 43, wherein the oxidizing agent additive is at least one of sulfur dioxide, nitrous oxide, carbon dioxide, a halogen, an interhalogen, 10 an oxychloride, a sulfur monochloride, a vinyl carbonate, and halogenated carbonates.

45. The method of claim 43, wherein the negative electrode is a glassy coated lithium electrode.

46. The method of claim 45, wherein a crack in the glassy coated lithium electrode is penetrated by the oxidizing agent additive contained in the electrolyte.

15           47. The method of claim 46, wherein the crack is filled with a reaction product between the oxidizing agent additive and the lithium material of the glassy coated lithium electrode.